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Diurnal. ⁶Ellis

Barometre

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ON THE

DIURNAL VARIATION

OF THE

BAROMETER

AT THE

ROYAL OBSERVATORY, GREENWICH.

BY

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It will be in the remembrance of those Fellows who were present at the last meeting of the Society that at the close of the meeting I exhibited some small diagrams of curves showing the diurnal variation of the barometer for months and for years, as deduced from the photographic records taken at the Royal Observatory during the twenty years ending 1873. A strong wish having been afterwards expressed for the numerical values of the variations for months, I mentioned this wish to the Astronomer Royal, who at once assented to the communication to the Society of the numbers in question. They are contained in the accompanying table, to which I propose to add a few general remarks.

In order better to show the character of the diurnal variation I have prepared an illustrative diagram (Plate XVIII.) giving the Greenwich curve for each month, but smoothing the small accidental irregularities. The curves apply to the civil day, commencing at midnight, the first six hours being repeated at the end of each curve to show better the form of the curve near to midnight. The thick horizontal lines indicate mean values. The spaces between the vertical lines represent each two hours, and the spaces between the horizontal lines each 0·01 inch of barometer reading. The points at which the dotted lines cut the curves indicate respectively the times of sunrise and sunset.

TABLE of the Diurnal Variation of the Barometer in each Month (or Excess of the Mean Reading at each hour above the Mean Reading for the Month), with the Mean Reading for each Month, as deduced from a discussion of the Photographic Records taken at the Royal Observatory, Greenwich, during the Twenty years ending 1873.

Hour.	[Communicated by the Astronomer Royal.]												For the Year.
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Midnight	+0029	+0029	+0100	+0048	+0108	+0070	+0084	+0069	+0071	+0089	+0088	+0010	+0066
1 a.m.	-0022	+0006	+0081	+0020	+0069	+0040	+0048	+0035	+0032	+0064	+0046	-0015	+0034
2 "	-0028	-0017	+0037	-0018	+0041	+0002	+0012	-0005	-0016	+0017	+0021	-0003	+0004
3 "	+0049	-0063	-0026	-0048	+0005	-0028	-0023	-0044	-0062	-0041	-0023	-0013	-0035
4 "	-0087	-0089	-0060	-0068	-0015	-0036	-0028	-0069	-0098	-0071	-0055	-0042	-0060
5 "	-0122	-0090	-0064	-0066	+0001	-0018	-0020	-0057	-0106	-0081	-0066	-0069	-0063
6 "	-0130	-0087	-0040	-0017	+0028	+0011	+0002	-0013	-0063	-0073	-0068	-0066	-0043
7 "	-0099	-0044	+0009	+0034	+0048	+0051	+0041	+0030	+0056	-0023	+0028	-0040	+0050
8 "	-0032	+0028	+0049	+0072	+0072	+0086	+0076	+0075	+0056	+0054	+0041	+0024	+0050
9 "	+0044	+0079	+0091	+0112	+0080	+0093	+0086	+0108	+0113	+0088	+0088	+0098	+0090
10 "	+0104	+0112	+0110	+0122	+0067	+0085	+0082	+0109	+0118	+0096	+0119	+0164	+0107
11 "	+0112	+0133	+0100	+0097	+0045	+0069	+0069	+0084	+0090	+0079	+0103	+0136	+0093
Noon	+0024	+0083	+0069	+0058	+0012	+0034	+0039	+0037	+0057	+0009	+0019	+0028	+0039
1 p.m.	-0060	-0014	-0002	+0011	-0034	-0011	-0002	-0004	+0006	-0078	-0059	-0069	-0026
2 "	-0087	-0081	-0073	-0043	-0073	-0045	-0032	-0040	-0036	-0116	-0109	-0109	-0070
3 "	-0051	-0110	-0124	-0107	-0120	-0089	-0071	-0087	-0088	-0143	-0113	-0090	-0100
4 "	-0016	-0109	-0150	-0132	-0140	-0119	-0107	-0113	-0113	-0137	-0098	-0068	-0109
5 "	+0018	-0080	-0144	-0138	-0156	-0145	-0140	-0137	-0116	-0096	-0057	-0046	-0103
6 "	+0049	-0017	-0098	-0122	-0145	-0141	-0142	-0134	-0086	-0031	-0016	-0023	-0076
7 "	+0079	+0034	-0042	-0066	-0104	-0105	-0108	-0085	-0020	-0023	-0010	+0006	-0032
8 "	+0088	+0054	+0005	+0011	-0031	-0048	-0049	-0001	+0039	+0058	+0023	+0025	+0014
9 "	+0086	+0081	+0053	+0066	+0057	+0058	+0038	+0064	+0072	+0101	+0047	+0041	+0064
10 "	+0080	+0086	+0063	+0088	+0085	+0085	+0071	+0090	+0078	+0105	+0043	+0049	+0077
11 "	+0068	+0085	+0063	+0093	+0098	+0099	+0079	+0099	+0065	+0100	+0037	+0061	+0079
Monthly Means	29.7294	29.8319	29.7217	29.8041	29.7772	29.8293	29.8087	29.7990	29.7873	29.7199	29.7626	29.7912	29.7802

The Hourly Values contained in this Table are such as are given by observation, without the application of any process, graphic or otherwise, for the smoothing of small accidental irregularities.

The Monthly Means are reduced to the Standard Barometer Newman, and corrected to 32°. No correction has been applied for elevation. The cistern of the Barometer is considered to be 159 feet above the mean level of the sea.

It will be seen that there are the usual double maxima and minima, indicating semi-diurnal inequality, or inequality with period of 12 hours. There is the morning minimum, the forenoon maximum, the afternoon minimum, and the evening maximum. There is, also, in most months, evident indication of a diurnal inequality, or inequality of 24-hours period, as shown by the greater depression of the second or afternoon minimum as compared with the morning minimum, and a tendency to greater depression in the second or evening maximum as compared with the forenoon maximum.

I have marked on the curves by short lines the positions of the maxima and minima. They are simply estimated positions, but will serve quite well for pointing out certain peculiarities. Comparing together the different months of the year, it will be seen that the morning minimum and the forenoon maximum both occur earlier as the year advances: they are earliest in summer, and become later again on the approach of winter. The afternoon minimum and the evening maximum, on the contrary, occur later as the year advances; are latest in summer, and become earlier again towards the end of the year.* They all change in a certain degree with the change in the times of sunrise and sunset. As a consequence of this the intervals between the morning minimum and the forenoon maximum, and between the afternoon minimum and evening maximum, do not change very much through the year, whilst that between the forenoon maximum and afternoon minimum is much shorter in winter than in summer, and that between the evening maximum and morning minimum is much longer in winter than in summer. An examination of the volumes of the Oxford observations shows that the same thing takes place at Oxford.

It is seen that although the diurnal or 24-hourly inequality is well shown in the Greenwich curves in nearly every month of the year, in one or two months it is less perfectly shown. But still it is a real, and not an accidental inequality. To illustrate this point I have prepared another diagram (Plate XVIII.), in which, using the same scale as before, I have given mean diurnal curves for various places at which good determinations have been made. For Greenwich (latitude $51\frac{1}{2}^{\circ}$ north) for the average of the whole 20 years; for Oxford (latitude $51\frac{3}{4}^{\circ}$ north) for the average of 17 years' observations (1858 to 1874); for Washington (latitude 39° north) for the average of 5 years' observations (1862 to 1866); for the Cape of Good Hope (latitude 34° south) from observations made between 1841 and 1846 (about 5 years); and for Ascension (latitude 8° south) from observations made between 1863 and 1865 (about 2 years). The Oxford, Washington and Cape curves depend on observations made at the observatories at these several places; that for Ascension depends on results contained in a volume recently published by the Meteorological Office.

* A slight inaccuracy is introduced into the comparison together of different months of the year, in consequence of the employment (as usual) of mean solar time instead of apparent time. It is, however, sufficient to remark the existence of the inequality, as its effect is practically unimportant in considering the broadly marked changes spoken of above.

The general similarity of the curves at these five different places is sufficiently apparent, and also the increase in magnitude of the variation as the equator is approached; the variations at Washington and the Cape being greater than those at Greenwich and Oxford, whilst that at Ascension is still greater. The approximate positions of the points of maxima and minima are marked by short lines as before. It will be seen that in these mean curves they occur at nearly the same times at all the five places. But with regard to variation in the times of occurrence of the maxima and minima in different parts of the year, pointed out as existing at Greenwich, it may be remarked as follows:—

At Ascension (latitude 8°) there appears to be no strongly marked effect of the kind. At the Cape (latitude 34°) there is some such tendency, especially as respects the afternoon minimum, which occurs much later in the Cape summer than in the Cape winter. But at Washington (latitude 39°) and Oxford (latitude $51\frac{3}{4}^{\circ}$) the variations in the times are strongly marked, and are altogether similar to those existing at Greenwich. They thus appear to be greater in the higher latitudes; but they are not apparently accompanied by change in the *amount* of the diurnal variation; for taking in each month of the year, the difference between the principal or forenoon maximum and the principal or afternoon minimum for Greenwich and for Washington (at both of which places the variations during the year in the *times* of occurrence of the maxima and minima are large), it is found that the mean difference for the six months from April to September at Greenwich is 0.024 inch, and for the six months from October to March is also 0.024 inch; and that at Washington the corresponding mean differences are: from April to September, 0.067 inch, and from October to March also 0.067 inch.

Reverting now again to the diurnal or 24 hourly inequality, it will be seen that it is distinctly indicated in each of the five mean curves by the unequal deviation of the two maxima and two minima from the zero line, and it has the same general character in each curve. It is much more strongly marked at Washington, the Cape, and at Ascension, than at Greenwich or Oxford. It is especially apparent in the Washington curve. And on examining the numbers for the different months at Washington and Ascension, it is found to be as strongly marked and to possess the same general characteristics at each of these places in all months of the year. A similar remark applies with nearly equal force to the Cape. But at Greenwich, where the whole diurnal variation is so much smaller, the general character of the diurnal or 24-hourly inequality appears to be a little modified in some months of the year, as is seen in the diagram showing the monthly curves for Greenwich.

The result of this is that in the daily variation of the barometer the diurnal and semi-diurnal inequalities are both real inequalities, representing real physical effects. Had methods of calculation been applied, we should probably have deduced other smaller inequalities of shorter period. But lesser inequalities may be in part accidental, and it was rather my wish on the present occasion to point out the connection of the diurnal and semi-

diurnal inequalities in a graphical way, because the general effect seems to be thus more readily perceived.

It seemed to me, however, that it might still be interesting to calculate the constants for the five mean curves, because they enable us to study more completely the peculiarities of each curve. The whole diurnal variation at the several places may be nearly represented by the following formulæ, in which x denotes the interval of time, expressed in degrees (15 to each hour), elapsed since midnight:—

	In.	In.	In.
Greenwich	$= + \cdot 0029. \sin (25 \cdot 4 + x) + \cdot 0090. \sin (142 \cdot 1 + 2x) + \cdot 0012. \sin (5 \cdot 0 + 3x)$		
Oxford	$= + \cdot 0034. \sin (51 \cdot 2 + x) + \cdot 0098. \sin (157 \cdot 6 + 2x) + \cdot 0010. \sin (35 \cdot 5 + 3x)$		
Washington	$= + \cdot 0186. \sin (348 \cdot 6 + x) + \cdot 0175. \sin (164 \cdot 3 + 2x) + \cdot 0016. \sin (351 \cdot 8 + 3x)$		
Cape of Good Hope =	$+ \cdot 0048. \sin (344 \cdot 7 + x) + \cdot 0195. \sin (161 \cdot 3 + 2x) + \cdot 0015. \sin (17 \cdot 6 + 3x)$		
Ascension	$= + \cdot 0112. \sin (17 \cdot 1 + x) + \cdot 0282. \sin (158 \cdot 2 + 2x) + \cdot 0006. \sin (126 \cdot 7 + 3x)$		

I mentioned at the last meeting of the Society that an arrangement of the Greenwich hourly barometer values for the whole 20 years, with reference to the time of the moon's meridian passage, results in giving no certain indication of lunar diurnal variation, although a small lunar diurnal variation would appear to have been detected at some places. We have seen, however, that the solar diurnal variation is, in comparison, large; and this points to the action of heat as its principal producing cause. The changes, in the course of a year, in the times of occurrence of the maxima and minima of the solar variation (spoken of in an earlier part of the paper) also point to the influence of heat. It would appear that the order of these changes may be stated generally as follows:—Near the equator there is not much change in the course of the year in the times of sunrise and sunset; neither does there seem to be much change in the times of maxima and minima in the diurnal barometric variation. But in high latitudes there is great difference in the times of sunrise and sunset in different parts of the year, and (as appears by the observations at Greenwich, Oxford and Washington, and in some degree by the observations at the Cape) corresponding great difference between the times of occurrence of the maxima and minima in the diurnal barometric variation. That is to say, in high latitudes the morning minimum and forenoon maximum appear to be both accelerated when the sun rises early, and the afternoon minimum and evening maximum both retarded when the sun sets late; whilst in low latitudes, where there is little change in the times of sunrise and sunset, there appears to be also little change in the times of the barometric maxima and minima.

*Lunar
tides*

X

DIURNAL VARIATION OF THE BAROMETER.

Mean Monthly Curves.—Royal Observatory, Greenwich, 1854 to 1873.

MIDN. 2 4 6 8 10 NOON. 2 4 6 8 10 MIDN. 2 4

January.

February.

March.

April.

May.

June.

July.

August.

September.

October.

November.

December.

Annual Curves at Different Places.

MIDN. 2 4 6 8 10 NOON. 2 4 6 8 10 MIDN. 2 4

Greenwich
Lat. $51\frac{1}{2}^{\circ}$ North.Oxford
Lat. $51\frac{1}{4}^{\circ}$ North.Washington
Lat. 39° North.Cape of Good Hope
Lat. 34° South.Ascension
Lat. 8° South.

The spaces between the horizontal lines represent 0.01 inch. The short lines crossing the curves indicate approximate positions of maxima and minima. The places at which, in the Greenwich curves, the dotted lines cut the curves, point out the times of sunrise and sunset at Greenwich.

